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Responsible Research and Innovation – how to develop RRI awareness among young people? European projects proposals and their results

Introduction – Why RRI?

As Bret L. Simmons wrote, "Today's problems come from yesterday's solutions" (2010). Such solutions included for example the use of asbestos – a mineral with unique properties: non-flammable, flexible, non-conductive of heat and electricity, resistant to chemical and physical factors. As a result, asbestos was widely used in the products applied in high temperature and in the environment of water, water vapour, active gases, organic and inorganic acids, greases, oils, solvents, exhaust gases, lye etc. (Szeszenia-Dąbrowska, 2008). However, the exposure to asbestos is a serious threat to human health. Although usually asbestos fibres are firmly linked, the mechanical processing of its products (e.g. cutting, drilling) and the so-called soft asbestos products used indoors in the form of thermal insulation or additives for paints and varnishes are dangerous to health and environment, and cause the emission of carcinogenic asbestos dust (Szeszenia-Dąbrowska, 2008). However, how did it all happen, despite the fact that in 1897 the first medical doctor linked emaciation and lung problems with the inhalation of asbestos dust, and the first documented fatal case related to the use of asbestos was reported in 1906, when the autopsy of an employee using asbestos revealed the fibrosis of his lungs; and in spite of the fact that it was not until 1970s when EPA (Environmental Protection Agency) and OSHA (Occupational Safety and Health Administration) began to legally regulate the use of asbestos (Barbalace, 2004), and in Poland the production of goods containing asbestos lasted until 1998 (100 years later)?

In order, among other things, to prevent such negative events in the future, but also to get closer to solving the most urgent social needs, such as the fight against diseases, access to clean water and adequate amounts of food, ensuring energy supply, waste disposal etc., the European Commission has been promoting the idea of *Responsible Research and Innovation*, the implementation of which is to contribute to better adaptation of the research and innovation process and its outcomes to the values, needs and expectations of the European society. In the description of the "Horizon 2020" programme one can read:

- There are times when science can seem to lose its connection to society and its needs, and sometimes its objectives are not fully understood, even if they are well intended.
- The lack of a common language and rapid progress in many areas of research has increased the public's concern or contributed to ambivalence about the role that science and technology play in everyday life.
- Europe wants to promote not only excellent, but also socially desirable science and technology.
- There is clear evidence that today we need to involve the whole of society in the decisions about the development of science and technology, so we can all contribute to the smart, sustainable, and inclusive growth of our societies (*Responsible research and innovation – Europe's ability to respond to societal challenges*, 2012)

What is RRI about?

According to the report by H. Sutcliffe (2011) RRI may be understood in the following ways:

1. The deliberate focus of research and the products of innovation to achieve a social or environmental benefit.
2. The consistent, ongoing involvement of society, from beginning to end of the innovation process, including the public & non-governmental groups, who are themselves mindful of the public good.
3. Assessing and effectively prioritising social, ethical and environmental impacts, risks and opportunities, both now and in the future, alongside the technical and commercial.
4. Where oversight mechanisms are better able to anticipate and manage problems and opportunities and which are also able to adapt and respond quickly to changing knowledge and circumstances.
5. Where openness and transparency are an integral component of the research and innovation process.

However, for the society to enjoy the opportunity to engage in the research and innovation process, it must have knowledge (science education) and be aware of the needs, opportunities (gender equality), conditions (ethics), objectives and have access to the plans and results of research, as well as proposals of implementations (open access).

RRI in the European Union projects

The first formal steps towards institutional support of RRI have been made as part of the Sixth Framework Programme (FP6), when the theme of "Science and Society" helped to increase the awareness among research and industry of the need to bring a range of research-related societal issues to the top of the policy agenda.

In 2007, the 7th Framework Programme entitled "Science in Society" was launched, and in 2014 – "Science with and for Society" (SwafS) came into existence across "Horizon 2020". In each of the projects, RRI has been a key element (*Research and Innovation. Science with and for Society. Evolution of the Programme*).

An example of an interesting project on RRI is **CONSIDER**, as part of which a web portal supporting the involvement of civil society in research has been developed (http://www.consider-project.eu/). There one can find an answer to the question: why would CSOs (Civil Society Organisations) be interested in participating in research projects? The answer is as follows:

- Because CSOs work on the ground, they are able to contribute field-based knowledge to research, drawing on tangible and relevant sets of feedback, data, studies etc.
- A CSO may want to act as a guardian for ethical issues in terms of methodology and outcomes.
- As research findings' may inform policy-making in a field that affects the interests or causes they represent, CSOs may want to get involved in order to help shape the research and favour a more evidence-based policy-making.

Moreover, practical tips for scientists can also be found in the web portal:

- Clarify your reasons for CSO involvement.
- Be aware of your local institutional support and recognition.
- Set your clocks: clarify likely timescales in advance.
- Agree on project management principles in advance (*Civil Society Organisations in Designing Research Governance*, 2013).

As part of the **Catalyst project**, an interesting model of communication between scientists and society has been developed (Fig. 1).

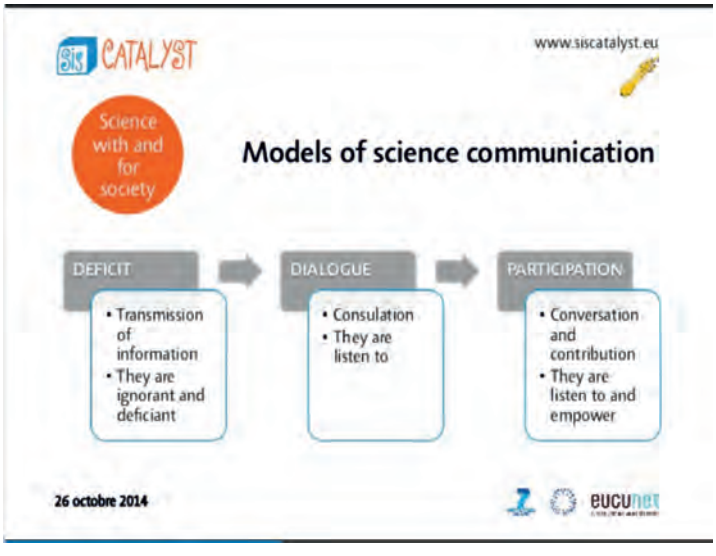


Fig. 1. Example of Project Catalyst materials (retrieved from http://www.siscatalyst.eu/)

An umbrella project, using the resources of many of the previous projects in the field discussed, is **RRI toolkit**. On their website all the necessary information, research results, activity outlines etc. have been published (Fig. 2).

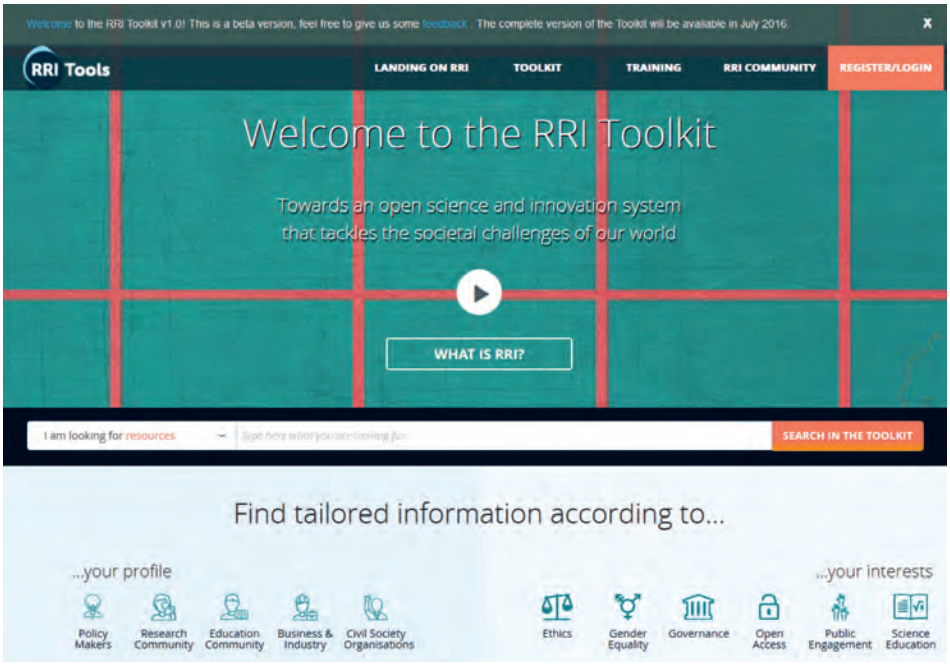


Fig. 2. RRI Toolkit (retrieved from http://www.rri-tools.eu)

The grant project of the **IRRESISTIBLE** (*Including Responsible Research an innovation in cutting Edge Science and Inquiry-based Science education to improve Teacher's Ability of Bridging Learning Environments*) acronym received funding in 2014 within the framework of activities coordinating and supporting the FP7--SCIENCE-IN-SOCIETY-2013-1 programme, activity 5.2.2 Young people and science, topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The work is coordinated by the University of Groningen (The Netherlands) with a Polish partner – the Jagiellonian University in Krakow (JU): Faculty of Chemistry and the Museum of the Jagiellonian University (Fig. 3). The main goal of the IRRESISTIBLE project is to design activities that foster the involvement of students and the public in the process of Responsible Research and Innovation.

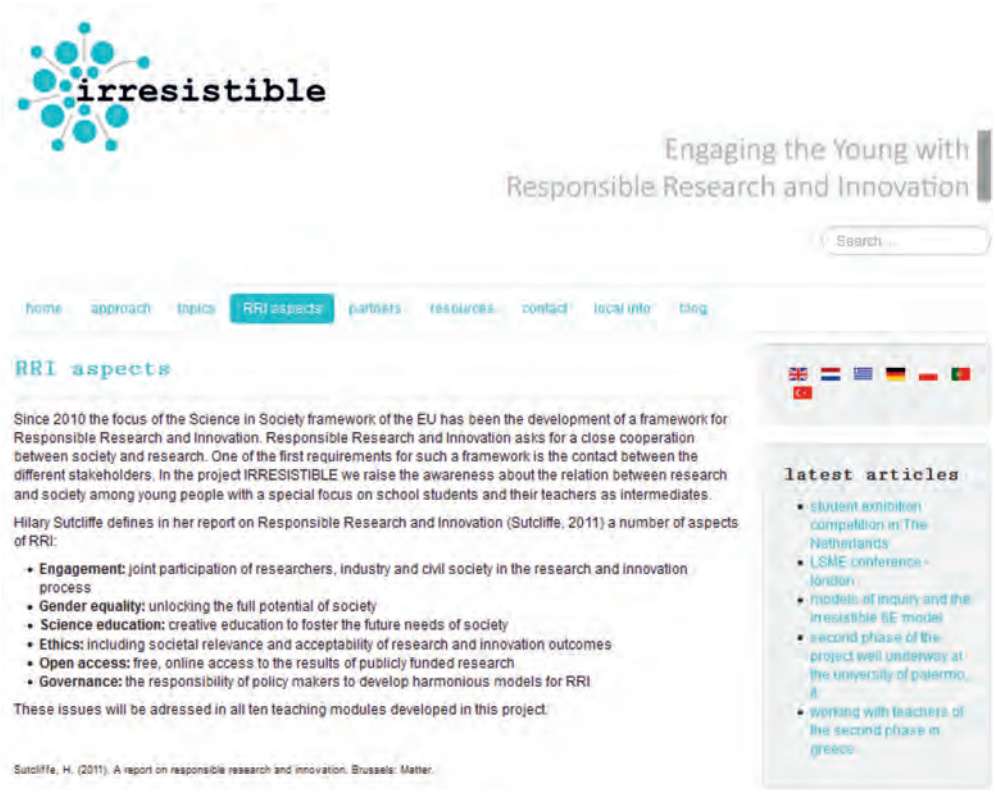


Fig. 3. RRI on the IRRESISTIBLE project website (retrieved from www.irresistible-project.eu)

How to develop RRI awareness – proposals of the IRRESISTIBLE project

Generally speaking, to raise the awareness on RRI, the IRRESISTIBLE project aims to increase students' content knowledge about Science by bringing cutting edge research such as nanotechnology into the school programme, and to foster the discussion among students about RRI issues by the introduction of relevant topics (IRRESISTIBLE project homepage, 2013). Wide public engagement is obtained for example by the preparation of students' interactive exhibitions.

In the first phase of the project the main task was to develop the modules: educational materials for teachers (lesson outlines) and students (worksheets, resources). One may say that in those modules RRI awareness was developed in two ways: in the form of CBL (Context-Based Learning), based on the example of such topics as "Nano in health sciences" or "Perovskite-based photovoltaic cells", as well as in the form of education in the field of NoS (Nature of Science) – classes dedicated to the discussion on how science develops, what the scientific method is, how scientists and research teams work etc. Some modules prepared in the project focused more on the selected items of RRI; other dealt with a number of RRI issues,

not necessarily closely related to chemistry, physics or biology, e.g. they concerned scientific career of women and their role in research teams.

In the teaching materials, ethical and ecological aspects of research conducted and innovations implemented are emphasized, especially those related to human health or environment protection. These include, for example, the release of nanosilver in the process of washing commercial products with bactericidal or bacteriostatic properties – the topic of experiments and discussions proposed in the module developed by Bogazici University, Istanbul, Turkey (Fig. 4).

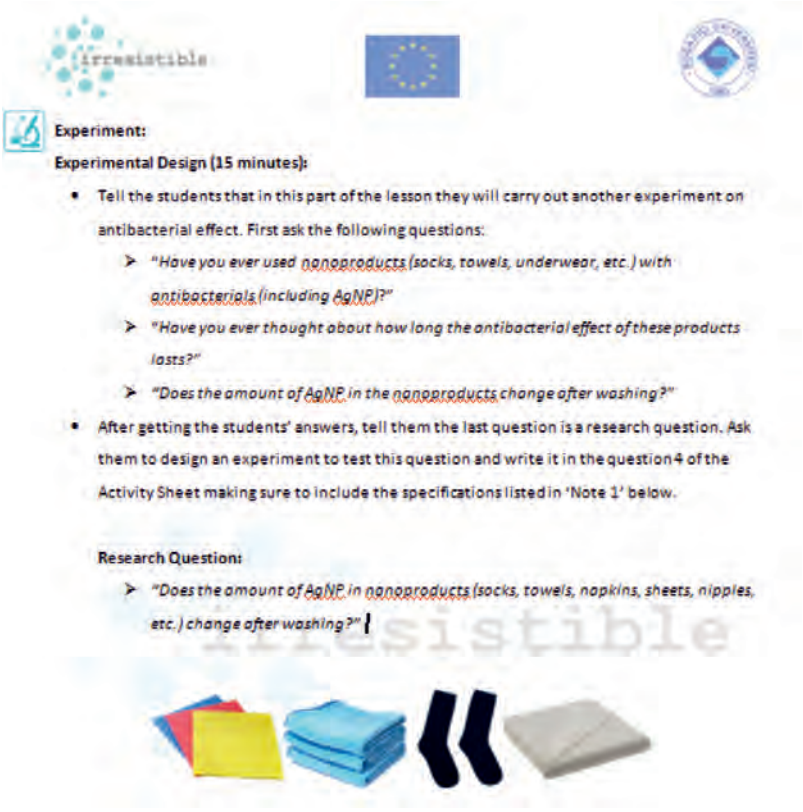


Fig. 4. Nanosocks – an example of students' activity (Nano in health sciences, 2015)

After the students examine the table (with the results of professional research concerning socks and water after various number of washings), the whole class takes part in a group discussion based on the following questions (Nano in health sciences, 2015):

- *"When you examined the table, what change did you notice in the samples in terms of the amount of Ag^+ ions?"*
- *"What caused this change?"*
- *"What does the presence of Ag^+ ions in the wash water indicate in terms of antibacterial effect?"*

- *"Considering that the wash water goes into the drainage system as waste, how might the Ag^+ ions in this water affect humans and the environment?"*
- *"In your opinion, how should the wash water of nanoproducts be disposed of? Why?"*

In the "Plastic – Bane of the Ocean" module prepared by IPN Kiel, Germany, the problems with the distribution of nano-size polymer particles in the environment are discussed.

Catalytic Properties of Nanomaterials – a module developed at the Jagiellonian University in Krakow

At the Jagiellonian University, a module entitled "Catalytic Properties of Nanomaterials", dealing with RRI in the context of sustainable development and especially environmental protection (air pollutions, automotive industry) has been prepared.

In this module two ways of introducing the topic of RRI and its individual pillars (6 key issues) have been used. Some activities are more related to chemistry aspects of the subject matter, and other activities are of a less science-related context. The former ones include for example the discussion on the person of Fritz Haber – both the inventor of a catalyst allowing for the synthesis of ammonia from gases present in the air, which enabled inexpensive production of nitrogen fertilizers and thus limited the scope of hunger, and a person who worked on the use of Zyklon-B in the Nazi concentration camps.

Jagiellonian University also suggests to consider here the issue of technological innovation in the automotive industry, including a wide variety of energy sources (diesel, gas, electric, hybrid cars). In this case, a panel discussion was proposed, in combination with the roles method. Students prepared their opinions and stands, learning e.g. how to search for and critically evaluate information. In the game, they represented the enthusiasts of different kinds of fuel, experts, industry representatives, non-governmental organizations, car owners etc. Another topic was the issue of the use of catalysts which, on the one hand, significantly reduce air pollution with nitrogen oxides and soot, but on the other require for their production the consumption of non-renewable natural resources, e.g. rare earth elements, as well as proper disposal or recycling. Recently, two new real-life items helping to engage students in discussions, based on authentic press releases and Internet news, have been introduced to the topic: the so-called Volkswagen gate – actions aimed at falsifying car engines emission tests (Fig. 5) and the cases of removing particulate filters from Diesel engines (Fig. 6).

Fig. 5. Internet News – example 1 (retrieved from http://www.bbc.com/news/business-34857404)

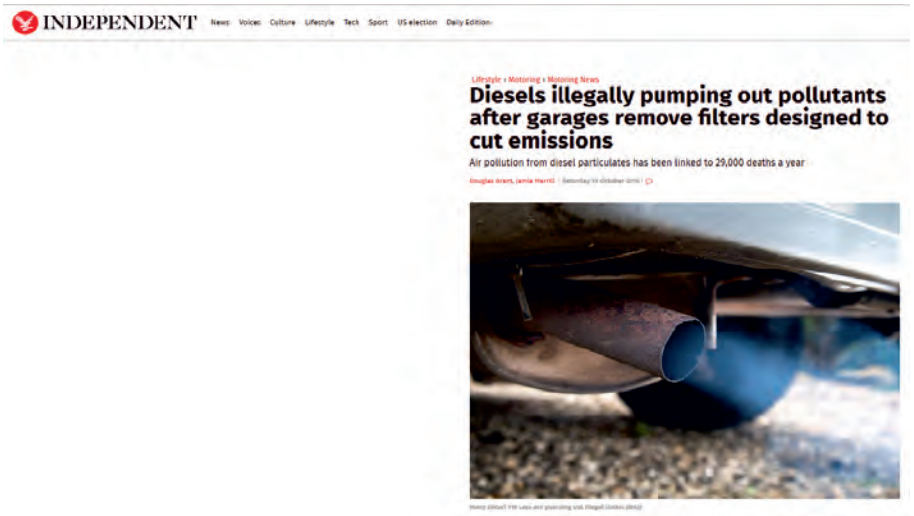


Fig. 6. Internet News – example 2 (retrieved from http://www.independent.co.uk/life-style/motoring/motoring-news/diesel-cars-illegally-pump-out-dangerous-pollutants-after-garages-remove-filters-designed-to-cut-a6689191.html)

Another approach implied the organization of classes focused on the process of conducting research and the work of research teams. In that case, the classes were based on group work, visits to research labs, discussions with researchers from the JU Faculty of Chemistry what is presented below.

Students worksheets – a tool for educational research

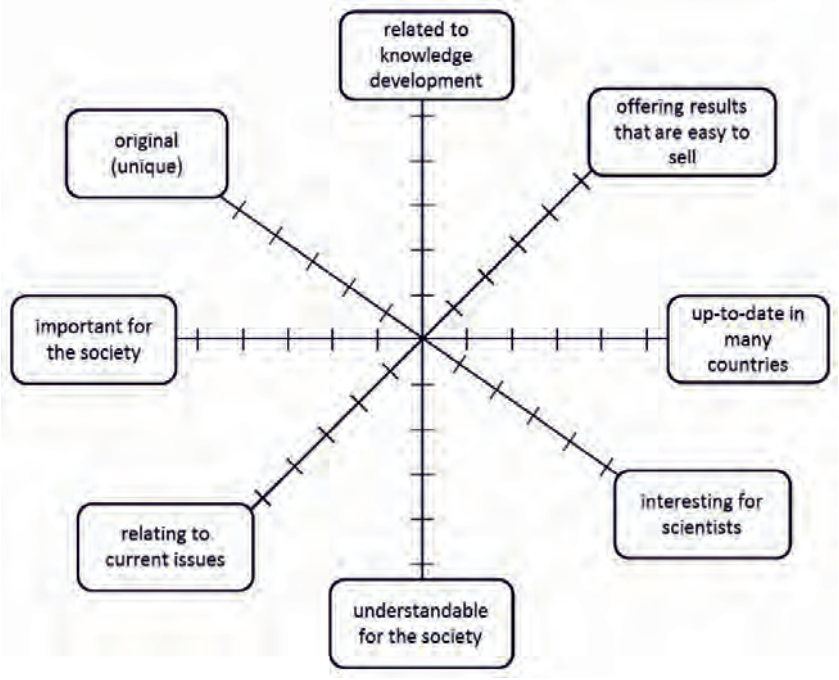
Below are presented worksheets of chosen students devoted to some elements of discussion about RRI issues developed by JU team (dr hab. Wacław Makowski, dr Paweł Bernard, dr Iwona Maciejowska) in the framework of IRRESISTIBLE project.

Research topics

1. What should be the features of a research topic?

Mark with a cross on the axis. If the feature is very important, mark near the outer end of the axis; if the feature is not very important, mark near the centre.

A research topic should be:



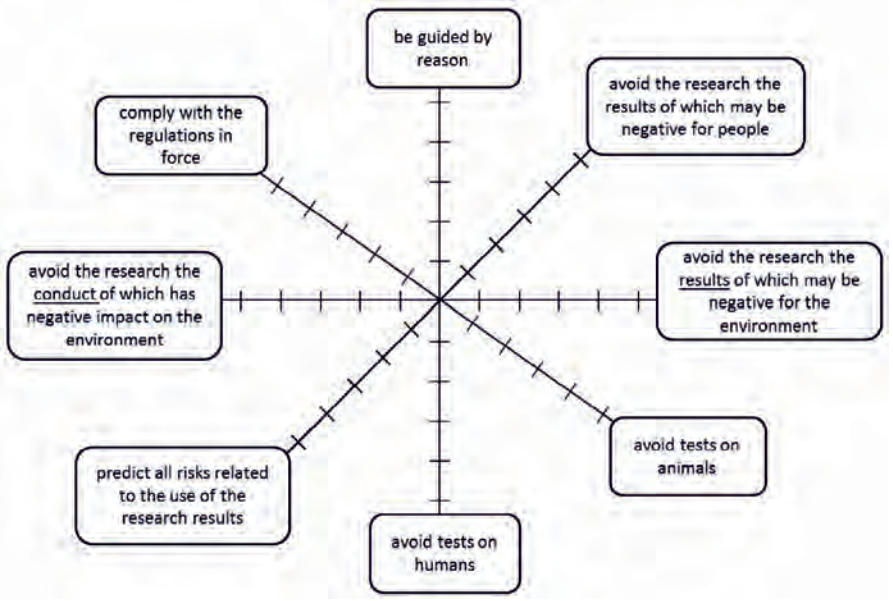
2. Mark one or several answers.

Who should decide on:	Scientists	Government	Society
a. the topic of the research			
b. science development directions			
c. industry development directions			
d. financing research			
The access to the research results should be granted to:			

3. Discuss your answers in the group, agree on the conclusions, write them down on the enclosed card, and then present them to the other participants of the meeting.

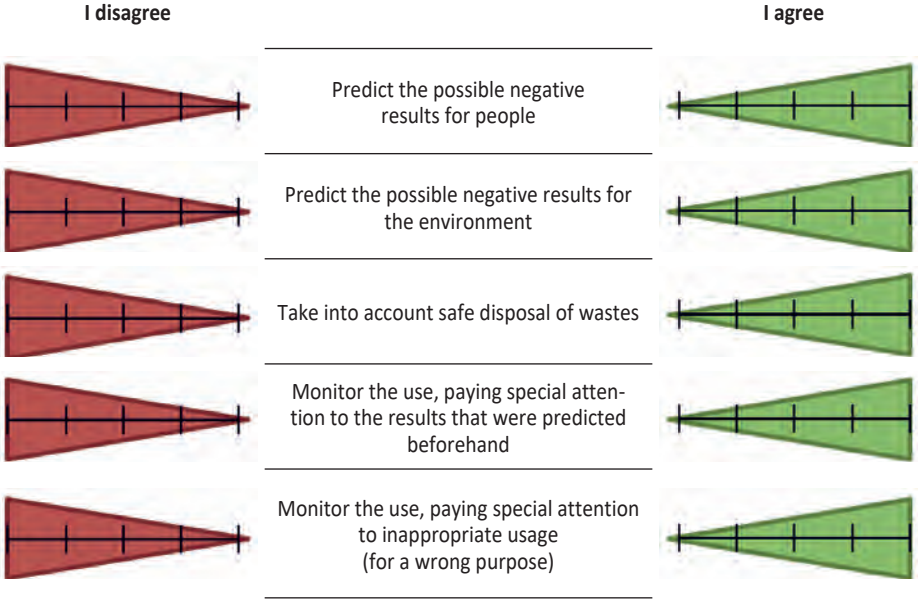
Ethics in scientific research

Scientist, when planning and conducting research, should:



Innovation and new technologies – implementation ethics

1. When implementing innovations and new technologies for widespread use, to what extent should the effects of their use be predicted? In the diagram below, select to what extent you agree with the following statements.
   Persons and institutions involved in the innovation implementation should:



2. Who bears the greatest responsibility for the consequences of the implementation of innovations and new technologies for widespread use? Arrange the items on the list in the order of importance:
   a) Government or self-government
   b) Producers
   c) Sellers
   d) Inventors
   e) Non-governmental organizations
   f) Users

Enter the proposed order (from the most to the least responsible) in the following diagram.

The analysis of the school students group responses provides a picture of their prior knowledge on the topic. The analysis covered the worksheets of 14 mixed-gender groups of lower secondary school students (3–6 persons each), completed in the school year 2015/2016 in various schools in the Małopolska region. The frequency and intensity/importance level (where adequate e.g. radar charts) in the opinion of the students were compared.

Results

When analyzing the qualities that research should demonstrate, it can be concluded that students do not think that scientists should decide on the directions of the development of industry or financing research work (only one positive response out of 14), but definitely they should decide on the topic of the research (greatest number of positive responses). In the students' opinion, the government should be involved in taking decisions on all the issues the students were asked about, especially those concerning the funding of research, and the least the issues concerning the topics and directions of science development. To some extent, the society should also have a say in all topics (on average half of the groups indicated each element). According to the majority of the students groups (9/14), the access to research results should be guaranteed to all groups: scientists, government and society.

When analyzing the students' opinions on ethical aspects of research, i.e. the answer to the question: "*When planning and doing research, to what extent should they be guided by proper rules?*", one may notice that in the students' opinion scientists, when planning and doing research, should first and foremost comply with the applicable law (average "importance" of 4.6 on a scale of 0–5), and to a much lesser extent they should be guided by their conscience (3.4). There is definitely

no unanimity on the necessity to avoid animal testing, and it is a principle the least frequently selected by the students (3.8).

Interestingly, the students pay more attention to the effects of the research process or results on the environment (on average 4.1–4.2, respectively) rather than on man (3.9). It was confirmed by the results of the analysis of worksheets dedicated to ethical issues of innovations and new technologies implementation, where the most frequently selected was the response concerning the necessity to anticipate the possible negative effects on the environment. In this worksheet, the statement that turned out to be particularly unpopular was the one saying that individuals and institutions involved in implementation of innovation should monitor that process in terms of its inappropriate use (for the wrong purpose). In this case, 4 groups marked the opinion "I do not agree", although with varying intensity. Here the authors of such worksheets had in mind, among other things, multiply use of chemicals, e.g. herbicides used as war gases, or medicines used as illicit drugs. Perhaps the statement was not sufficiently clearly defined. Two groups did not agree either with the statement that people introducing innovations should take into account the safe disposal of the products used.

According to lower secondary school students, the responsibility for the consequences of the introduction of innovations for everyday use is distributed as follows (from the greatest to the lowest responsibility):

government or local government > inventors > manufacturers > NGOs > sellers > users

Conclusions

There are many strategies and methods of introducing RRI to formal and informal education, more or less related to the context of natural sciences. Mass media provide the descriptions of interesting cases, allowing to make the topic of responsible research and innovation relevant for students. It is worth using those examples in order to implement the rule of involving the entire society in this process. Many European projects offer interesting resources which can support teachers efforts.

Although the issue of misconceptions in chemistry has been so far discussed in numerous publications, including books (Barke et al., 2009; Taber, 2002), the misconceptions concerning the conduct of scientific research, operation of research teams and implementation of innovations are still "terra incognita". The one exception is the so-called "image of a scientist", e.g. in Saleh and Khine book (2011).

It is worth looking for the sources of large discrepancies between the assessment of the role of the scientist's conscience and the applicable laws, to the detriment of the former. This may be due to both downgrading the role of the personal assessment of the situation (conscience) in favour of external conditions (legal regulations), as well as to the exceptionally low level of social trust in Poland (see the results of the European Social Survey of 2014, in which Poland is ranked at the bottom of the

ranking of trust), in this case the belief in the high level of ethical competence of scientists. The studies allowing to compare the opinions on those issues of young people from Poland and other countries representing a different level of social trust would be interesting. The students' opinion on an insignificant responsibility of innovation users for the consequences of innovation implementation may confirm the thesis of declining the responsibility by young people, or speaking their language – of desiring to "release oneself from thinking". Especially the fact that the results of the discussions in two groups pointed out to the disregard for the problem of safe disposal of the products used must worry and requires corrective actions.

Derek Bok sad 15 years ago: "Taking citizenship seriously is, in the end, not a natural thing (…). Civic responsibility has to be taught in our schools and in our universities and reinforced by the media in later life and nurtured by all kinds of civic associations and activities in the society during one's mature years" (Bok, 2001). Those words are still valid especially in the context of Responsible Research and Innovation.

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Responsible Research and Innovation – how to develop RRI awareness among young people? European projects proposals and their results

Abstract

The need for research and innovations implemented in a responsible way is nothing new, but so far it has mainly concerned the scientific community. In the twenty first century, however, it is not enough and it is worth involving the entire society in the process. The main challenge is to find effective methods to encourage all stakeholders to participate in the RRI process. This task has been taken up by, among others, the partners of the educational project of the 7th Framework Programme, i.e. the IRRESISTIBLE project. The developed teaching materials are to assist teachers in the implementation of the RRI issues in the context of cutting edge science, using the inquiry-based (IBSE) teaching strategy, and in the development of non-formal education implemented in cooperation with museums and science centres. Module prepared by Jagiellonian University team proposes two ways of introducing the topic of RRI and its individual pillars (6 key issues): some activities are more related to chemistry aspects of the subject matter in the context of air pollution and car industry, and other activities are more located in the field of NoS (Nature of Science) – classes dedicated to the discussion on how Science develops, what the scientific method is, how scientists and research teams work. The results of the research conducted among lower secondary school students in Poland show the need to develop their sense of responsibility and the need of involvement of students in the process of responsible research and innovation, as well as the correction of some alternative conceptions related to that subject.

Key words: Responsible Research and Innovation, educational projects

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